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High Temperature Superconducting Microwave Device

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Thin films of the high-T_c superconductor Bi-Sr-Ca-Cu-O were prepared by sputter deposition. The films were deposited at room temperature and then post deposition annealed. A microwave measurement system based on a microstrip resonator was established. X-ray diffraction revealed that the films were multi-phase. Resistance of these films did not show a transition when cooled to liquid nitrogen temperatures.

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INTRODUCTION

High temperature superconducting materials offer the potential for producing passive microwave devices, such as resonators, detectors, filters, delay lines, etc., that have orders of magnitude better properties than standard metal systems. Microstrip line resonators made of superconducting materials exhibit higher Q values than copper lines, when operated at temperatures below their superconducting transition temperature. High temperature superconducting materials are leading to a new technology of high frequency miniature microwave circuits.

Commercial high temperature superconducting devices are commonly made using films of the 123 Y-Ba-Cu-O system or the Tl-Ba-Ca-Cu-O system. The system Bi-Ca-Sr-Cu-O has superconducting phases but is not generally used to make devices. This system forms a multiphase system that cannot be separated to form a single phase film. The system gives two superconducting transition temperatures that occur near 120K and 90K.

Our research work over the past year has involved:

(1) work to prepare thin films of the system Bi-Ca-Sr-Cu-O by RF sputtering;

and

(2) assembling a microwave system for measurement of the properties of the high temperature superconducting materials and devices.

THIN FILM PREPARATION

The films were deposited by sputtering onto substrates that were not heated during the deposition. The films were taken out of the sputtering chamber and placed in a furnace for annealing.

X-ray diffraction measurements that I made on the films did reveal that the films were multi-phased. One phase that was identified was the 2-1-2-2 superconducting phase of the Bi-Ca-Sr-Cu-O system [for comparison I used the data given in a reference by R. M. Hazen et al., Phys. Rev. Lett., 60, 1174 (1988]. The surface of the films was also examined using a microscope. The microscope showed that the films were not homogeneous and of good quality. The films consisted of small isolated islands or beads of metallic looking regions.

I did not perform magnetic susceptibility measurements on the films. However, I did make a simple resistance measurement. The samples has a very high resistance, and their resistance did not indicate a superconducting transition down to liquid nitrogen temperature.

We attempted to prepare thin films of the system Bi-Sr-Ca-Cu-O by RF sputtering. For our sputtering system we needed two-inch diameter targets. We made our targets, which proved to be a difficult task. This compound is a ceramic material and tends to crack or crumble. The targets were made using appropriate amounts of the compounds Bi_2O_3,$CaCO_3$,$SrCO_3$, and $CuCO_3$. The powders were mixed, fired at about

800°C, the resulting compound was ground to a powder, then this power was pressed into a disk. This disk was then placed on an AlO_3 disk and heated to 900°C and held there for about 2 hours. The disk was then slowly cooled to room temperature.

The target was used to sputter films onto ZrO_2 substrates. Our system is in RF magnetron sputtering system. Argon was used as the working gas.

The films were analyzed by x-ray diffraction measurements to identify the superconducting phases. Figure 1 shows the x-ray diffraction pattern for one film sample. The lines that correspond to the superconducting phase are marked in the figure.

MICROWAVE MEASUREMENT SYSTEM

The work over the past year also dealt with putting together a system for making microwave surface loss measurements on superconducting materials. I purchased a Hewlett Packard 8756A Scalar Network Analyzer with a sweep oscillator that can make measurements from 0.01 to 18.6 GHz. This equipment was a reconditioned system. A sample probe was constructed that allowed samples to be measured at low temperature. The probe was constructed similar to the probe of Dr. Anlage at the University of Maryland (the system is described in Rev. Sci. Instr. 62, 1801 (1991) and Rev. Sci. Instr. 61, 2201 (1990). The sample probe was machined in our Machine Shop.

The system allows the microstrip resonator technique to be used which is a very sensitive method for measuring the magnetic penetration depth and surface resistance of superconducting films. Our reconditioned network analyzer was found to work very well. We are presently limited in testing our measurement system, because we did not have a quality thin film sample or a superconducting microwave resonator or other device to test.

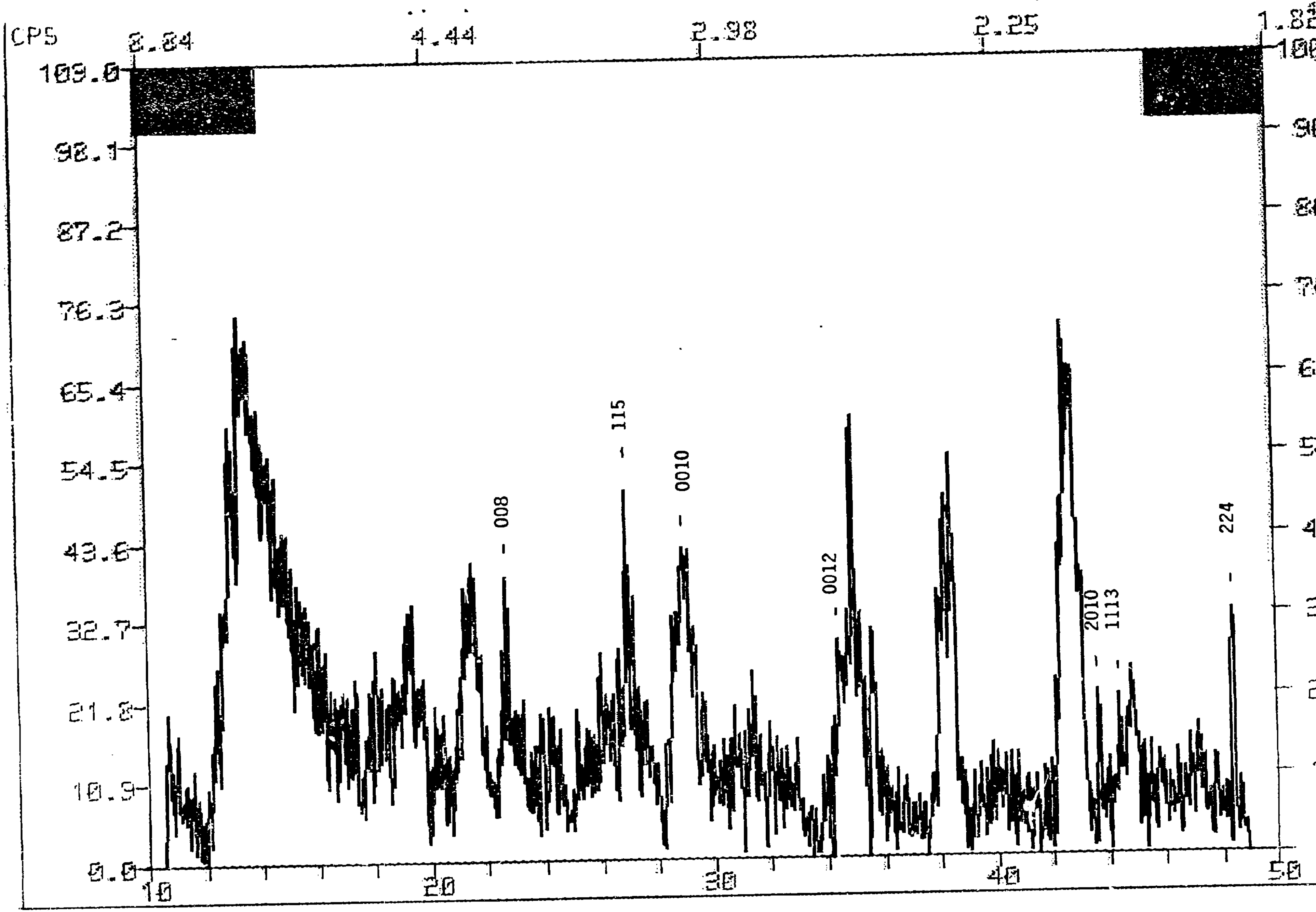

FIGURE 1
X-Ray Diffraction Intensity vs. 2θ Bi-Si-Ca-Cu-O film on ZrO_2 substrate.